AMENDMENTS TO THE SPECIFICATION

The following are replacement paragraphs for the specification including amendments thereto designated by markings showing the changes made to the immediate prior version.

Replace the paragraph beginning on page 8, line 11 and ending on page 9, line 18 with the following paragraph:

In prior art nerve integrity monitoring devices, controls for off-line functions consist of front panel knobs and switches or keyboard and mouse with proprietary software to perform common setup functions and parameter adjustments. Additional back panel switches may be available to adjust less commonly changed parameters, such as stimulus rate and duration. For multi-channel nerve integrity monitoring with qualitative and quantitative signal analysis, front and back panel hardware is cumbersome and too limited in scope. Greater flexibility and convenience in off-line controls is available through use of keyboard and mouse input and software capabilities to modify and store setup information in archival files for facilitation of off-line setup functions. A limitation of prior art strategies is that the setup information is held in volatile memory during actual monitoring operations, rendering the setup information vulnerable to strong electrical surges, electromagnetic noise or accidental power interruptions. An electrical surge or accidental unplugging may cause loss of all new (different from "default") setup information, requiring a "reboot" of the system and adjustment to get back to the desired settings. Any method for off-line control allowing similar flexibility ~~a~~ to keyboard and mouse input and having the convenience of designated software with archival (file) storage of setup information, but without risk of

erasure by spurious electrical events or accidental equipment unplugging, would represent a significant advance for nerve integrity monitoring. Stimulation devices of the prior art for neurophysiological monitoring are manually controlled through front panel potentiometers and switches or with mouse and keyboard to produce paired or burst stimuli and stimuli of opposite polarity in an alternating pattern, but lack the ability to deliver consecutive stimuli of differing intensities or alter the pattern of stimulation at a predetermined time without that time consuming manual input. Analogously, none of the monitoring instruments of the prior art provide delivery of selected stimuli in coordination with data acquisition, analysis, display, and storage. Moreover, ~~In~~ in prior art nerve integrity devices, control of on-line functions is performed by keyboard and mouse or by front panel controls and, because of a possible breach of sterility, the operating surgeon cannot perform such functions by himself or herself and so changing equipment settings requires involvement of hospital personnel at the request of the operating surgeon and may be time-consuming, cumbersome and possibly risky, since the changed settings may be inaccurate. Any method allowing rapid and accurate changes in equipment function without the need of ancillary operating room personnel and without risk to maintenance of sterility would be considered an enhancement of nerve integrity monitoring.

Replace the paragraph beginning on page 12, line 4 and ending on page 12, line 8 with the following paragraph:

There is a need, then, for a nerve integrity monitoring instrument having greater flexibility and stability in use, greater sensitivity and specificity (e.g., noise rejection and artifact identification), and a user interface more readily adapted to performing the

monitoring procedures required without distraction to the surgeon while concentrating on the medical aspects of the surgical procedure.

Replace the paragraph beginning on page 12, line 21 and ending on page 13, line 6 with the following paragraph:

In accordance with the present invention, an intraoperative neurophysiological monitoring system includes a number of novel features, including: a digitally controlled stimulator having multiple independent stimulus outputs; an artifact detection electrode with modified wire leads to enhance its sensitivity for recording electrical artifacts; a novel method and algorithm for detecting brief artifacts using the artifact detection electrode and an enhanced method and algorithm for threshold detection; a method and algorithm for controlling the sequence of monitoring events controlled by detection of probe contact with tissue; and a method and algorithm for controlling operation of the nerve ~~interity~~ integrity monitoring system in which the electrical stimulus probe is used as a computer pointing or input device.

Replace the paragraph beginning on page 13, line 7 and ending on page 13, line 16 with the following paragraph:

The intraoperative neurophysiological monitoring system stimulator preferably includes a nerve integrity monitoring instrument having multiple independent stimulus outputs to provide optimal preset stimulus output parameters for more than one probe type, thereby allowing all probes to be connected at the beginning of the case and used as needed, without delay or confusion related to switching and intensity setting changes. Independent, electrically isolated outputs also eliminate parallel connections among stimulus probes and possible current leakage between probes. An optimum number of stimulus outputs is preferably in the range of two to four. In an exemplary

embodiment, three stimulus outputs include a monopolar probe, a bipolar probe and an electrified instrument, all three simultaneously connected.

Replace the paragraph beginning on page 15, line 5 and ending on page 15, line 25 with the following paragraph:

4. While controversial, constant voltage has been cited as more advantageous than constant current for purposes of electrical stimulation, as a means to reduce the occurrence of false-negative stimulation in the setting of stimulus shunting (Moller A, Janotta J.: Preservation of facial function during removal of acoustic neuromas: use of monopolar constant voltage stimulation and EMG. J. Neurosurg 61: 757-60, 1984). Since stimulus current is the aspect relating to stimulus adequacy and injury potential, most applications incorporate constant current stimulus sources for greater accuracy and safety in stimulus delivery. Continuous measurement of stimulus circuit impedance allows a "best of both worlds" opportunity. Stimulus probes and electrified instruments have characteristic or optimal impedance values based upon the contact surface of the particular instrument. A reduction of impedance below that of the characteristic value is taken as an indication of stimulus shunting, presumably away from the area intended for electrical stimulation. This is particularly apt to occur with use of electrified instruments, where the ~~Insulation~~ insulation is not carried all the way to the tip so as to not ~~Interfere~~ interfere with ~~Its~~ its surgical use. In combination with digital control of stimulus parameters, detection of a stimulus circuit impedance decrease below the pre-determined "optimal" value is used to trigger a compensatory increase in delivered stimulus current in a pre-determined fashion. The rate of change or slope of current increase, relative to the amount or percentage of impedance decrease, is preselected for aggressive or less aggressive compensation patterns and an upper limit of current increase is also predetermined for safety considerations. Such a

compensatory current increase is safer and more reliable than simple use of constant voltage.

Replace the paragraph beginning on page 16, line 15 and ending on page 16, line 25 with the following paragraph:

In addition to detecting and responding to a temporal pattern of continuous tissue contact of the stimulus probe, the present stimulator is adapted for digital control. Stimulus intensity, pulse duration, and temporal pattern of stimuli presentation are controlled through a digital controller having an interface circuit. The interface stores pre-programmed stimulus algorithms or paradigms, preferably in ~~non volatile~~ non-volatile memory. The stimulus paradigms are preferably constructed off-line using appropriate stimulus control algorithm development software and is preferably loaded or burned into a non-volatile Read Only Memory (ROM) chip, included within the interface. During a monitoring procedure, contact with tissue will trigger a predefined sequence of events called, for purposes of nomenclature, a Tissue Contact Initiated (TCI)-Timeline, thereby activating the stored stimulus paradigms in a pre-programmed manner.

Replace the paragraph beginning on page 17, line 1 and ending on page 17, line 9 with the following paragraph:

Front panel controls consist of basic stimulus intensity controls. Stimulus, pulse duration and pulse repetition rate are preferably adjusted in a limited manner by recessed DIP-switches or other user-accessed, but less prominent controls. The remaining stimulator controls are actuated through a CPU interface, such as via a PCI bus. As discussed above, monitoring parameters and complex stimulus paradigms are stored via ~~non volatile~~ non-volatile, programmable memory (e.g., flash memory, EEPROM). The digitally controlled stimulator executing the TCI event-sequencing time

line also communicates with a CPU based data storage and analysis apparatus to direct binning of responses and to trigger archival data storage, analysis and display paradigms.

Replace the paragraph beginning on page 17, line 23 and ending on page 18, line 21 with the following paragraph:

Turning now to another aspect of the monitoring system of the present invention, a method is provided for detection and identification of artifacts as an aid to interpretation. For the purposes of this description, ""intelligent" refers to electrode sites ~~Involving~~ involving important "monitored" muscles, supplied or enervated by a particular nerve of ~~Interest~~ interest. Non-intelligent refers to other electrode sites within or outside of muscles, not supplied by the nerve of ~~Interest~~ interest. Current artifacts and electromagnetic field noise may best be detected by a specially constructed electrode that is inserted proximate to the recording field, but not in the (intelligent) muscles supplied by the nerve being monitored. Electrical events, simultaneously recorded in both "intelligent" electrodes (placed in muscles supplied by the nerve being monitored) and a "non-intelligent" artifact detection electrode, may be unambiguously interpreted as electrical artifacts. If the artifact detection electrode is placed in a nearby (non-intelligent) muscle not supplied by the nerve being monitored, it may also serve to detect light anesthesia. If repetitive EMG activity is simultaneously observed in monitored muscles and other muscles, it may be interpreted that the patient is beginning to wake up from anesthesia. The anesthesiologist may use this information to maintain adequate levels of anesthesia throughout the procedure. The operating surgeon may also be reassured that the observed nerve irritability is not related to surgical manipulations. The artifact detection strategy involves the construction of an artifact-detection electrode, preferably the electrode of the present invention is a

modification of the electrode design of U.S. Patent 5,161,533 (as discussed above). The modification provides a greater impedance imbalance between the two electrode leads, thereby reliably enhancing the antenna-like qualities of the probe and the susceptibility for detecting current and electromagnetic artifacts occurring in the immediate proximity of multiple standard electrodes placed in muscles supplied by the nerve of interest.

Replace the paragraph beginning on page 21, line 11 and ending on page 21, line 14 with the following paragraph:

The accuracy of the present artifact-detection strategy is dependent upon the strength of the recorded signal. Weak signals that only appear in a single channel may not distribute among ~~Intelligent~~ <u>intelligent</u> and ~~non-Intelligent~~ <u>non-intelligent</u> electrodes as predictably as when multiple electrodes are activated.

Replace the paragraph beginning on page 22, line 4 and ending on page 23, line 18 with the following paragraph:

In the present embodiment, threshold detection is improved through the use of digital signal processing (DSP), whereby all recorded electrical activity is digitized and evaluated for mathematical properties. A preferred measurement for EMG activity is rectified root mean square (rRMS), which gives a greater dynamic range for EMG activity magnitude, as detected by standard electrodes (e.g., as in U.S. Patent No. 5,161,533, discussed above). The greater dynamic range capability improves the ability to distinguish responses, based upon the magnitude of signal power. For example, while electrical artifacts and EMG responses show considerable overlap, the peak signal power of a non-repetitive (localizing) EMG activity is usually significantly higher than for a repetitive (non-localizing) EMG activity. The digitally processed rRMS data stream for each recording channel is continuously analyzed by software for peak

and average power within a variable time (probe) window. The width of the probe window (or dwell) over which power is analyzed may be varied in width (duration) up to one second, which may be "tuned" to give desired fractionating tendencies. For example, ~~If~~ if a minimum average power value is used for determining the event detection threshold, a narrow dwell time will reduce the dynamic range and improve detection of brief responses. Lengthening the dwell time will increase the dynamic range and favor selection of only larger overall responses. Alternatively, use of peak power determinations effectively neutralizes the effect of response duration, but may have the greater ability to distinguish repetitive and non-repetitive responses. Predetermined criteria for threshold detection may include minimum values for average power, peak power or both in some combination or ratio. The use of two distinct probe windows (described in Non-Provisional Patent Application No.), separated by a variable time (inter-probe ~~Interval~~ interval) allows greater accuracy in distinguishing brief non-repetitive (< 1.0 sec) and longer repetitive (> 1.0 sec) electrical events. If the inter-probe interval is selected to be one second, DSP (rRMS) data appears, via digital scroll, in the second probe window the same as it appeared in the first window, but one second later. A software algorithm may detect a supra-threshold event in the first probe window and re-analyze it one second later in the second probe window. At the time of detection of a supra threshold event in the second window, the activity in both windows is compared. If there ~~Is~~ is no supra threshold activity in the first probe window, the activity appearing ~~In~~ in the second window had a duration of less than one second. If supra-threshold activity occurs simultaneously in both windows, the duration of the activity observed ~~In~~ in the second probe window is taken as equal to or greater than one second. The inter-probe interval may be varied as a means to distinguish responses greater than or less than the selected interval value~~,~~. This additional

strategy may further enhance the ability to discretely select which events are to be analyzed by the artifact detection logical circuit for feedback to the operating surgeon. As ~~Indicated~~ indicated previously, small amplitude responses, which distribute to only one recording channel, and brief (1.0 sec) repetitive EMG responses may be analyzed relatively inaccurately by the present artifact-detection strategy. During surgical procedures, single or weak responses may be of important localizing value.

Replace the paragraph beginning on page 23, line 19 and ending on page 24, line 7 with the following paragraph:

Optionally, additional DSP analysis is used to help distinguish localizing non repetitive EMG activity from electrical artifacts and brief epochs of repetitive EMG activity. For example, supra-threshold electrical events can be captured into a stable buffer for DSP analysis. Additional mathematical treatment of rRMS data is employed for acquisition of additional features which are distinct from those selected for general threshold detection purposes. Repetitive EMG activity typically exhibits a more even power distribution than non-repetitive EMG activity. A comparison or ratio of peak and average power distinguishes the two activities. The values of peak and average power required to achieve a reliable fractionation are altered within the software and different initial mathematical treatment of DSP data, such as fast Fourier transform, may be useful in separating artifacts and EMG. However, additional DSP methods are presently considered to be less reliable than the use of "~~Intelligent~~ intelligent" and "non-intelligent" distributions for distinguishing artifacts and EMG activity. Their use is preferably user enabled and software algorithms are capable of periodic updates in order to take advantage of the accumulation of empirical data.

Replace the paragraph beginning on page 24, line 8 and ending on page 24, line

22 with the following paragraph:

In one embodiment, the output of an additional DSP analysis is available as an additional input to the logic circuit, involved with detecting "intelligent" and "non-intelligent" distributions of supra threshold events. Alternatively, outputs of the logic circuit and the additional DSP may provide input to a separate (third) controller, containing software algorithms for decision making. In either case, the software algorithms may ~~Incorporate~~ <u>incorporate</u> a hierarchy or system of assigning emphasis or "weight" to various inputs. For example, if electrical activity is detected simultaneously in the artifact detection electrode with a supra-threshold event detected in an "non-intelligent" location, this input suggests that the supra-threshold event was an artifact and may override any other DSP input to the contrary. Alternatively, if there was no simultaneous activity seen in the non-intelligent electrode, but a supra-threshold event is observed in only one of three or four active "intelligent" channels, the confidence that this is a true EMG response may be considerably less assured. In such an instance, a hierarchy may be constructed within the decision making software algorithm that may allow certain DSP data to override the initial "verdict," based upon spatial distribution.

Replace the paragraph beginning on page 25, line 12 and ending on page 26, line 6 with the following paragraph:

The inventor has observed that surgeons use the stimulus probe differently for locating and "Mapping" than for quantitative analysis of the functional status of nerves of interest. Temporal aspects of stimulus probe use can be monitored by the tissue contact detection capability within the digital stimulator as described previously. A signal is generated in the stimulator that relates to the period of continuous contact of

the stimulator probe with patient tissue. The signal continues as long as continuous tissue contact is maintained and is delivered to a system controller, which is able to initiate multiple predetermined sequential and parallel operations within the nerve ~~Integrity~~ integrity monitor. These operations relate to delivery of preprogrammed stimulus sequences and to the acquisition, analysis, display and archival storage of EMG data. Whether the predetermined operations are initiated or completed depends upon the duration of continuous tissue contact. For example, if the duration of continuous tissue contact is less than a preselected period of approximately one or two seconds, the controller will maintain the operational status of the nerve ~~Integrity~~ integrity monitor in the "search" mode. However, if the duration of continuous tissue contact exceeds the preselected time period, the stimulator or controller may alert the surgeon with an indicator tone and the controller will automatically change the operational status of the nerve integrity monitor to a quantitative assessment mode. The ~~Indicator~~ indicator tone may also be designed or configured to signify whether or not adequate current and/or stimulator circuit impedance has been achieved, as an indication of quality assurance.

Replace the paragraph beginning on page 26, line 7 and ending on page 26, line 18 with the following paragraph:

From the time of tissue contact detection, a digital clock is initiated, controlling a preset sequence of events through a controller ~~Interface~~ interface. For the purposes of this description, the period of continuous tissue contact of the stimulus probe is termed the "dwell" or "dwell time", and the series of preselected operational changes provoked by the "dwell" is termed, the "Tissue Contact Initiated Event Sequencing Time line" or

"TCI-Time line". The control method to be described is designed for use with the main stimulus probe (e.g., stimulus output #1) and may be used to control all functions of the nerve integrity monitor in a preselected fashion. The described methodology need not be limited to medical applications, in that the use of any probe, where its period of dwell can be measured, may be similarly configured to control multiple functions. The following description involves the preferred embodiment, although many possible sequence strategies are available through the TCI-Time line:

Replace the paragraph beginning on page 26, line 19 and ending on page 27, line 15 with the following paragraph:

Through the associated controller and controller interface, the onset of dwell will cause the artifact-detection circuit to be suspended ("defeated") throughout its duration and a preset pattern of stimulus pulses, the intensity of which is determined by front panel controls, will be delivered through the stimulator probe for locating and "mapping' the physical contour of the nerve of ~~Interest~~ interest. After a preselected dwell time of approximately one second, front panel control of stimulus parameters is defeated, the pattern of stimuli is changed from single pulses to alternating paired pulses with single pulses, the intensity of which is somewhat greater (supra-maximal), and the provoked EMG responses are digitized and individually captured into stable buffers. If the dwell is interrupted before a dwell of 2 seconds, the TCI-Time line is inactivated, the artifact-detection circuit ~~Is~~ is enabled, the stable buffers are cleared of captured signal and pulsed stimuli are no longer delivered through the stimulus probe. After a 2 second preselected period of dwell, the controller and associated interface initiate a signal processing sequence, where the captured responses ~~In~~ in stable buffers are analyzed

by averaging the single and paired responses separately and computing the difference between the paired and single response by digital subtraction. The magnitude of the single and digitally subtracted responses are computed and compared. A scalar value relating to a ratio of the magnitudes of the digitally subtracted response and the single response is stored in a spreadsheet against the absolute or lapsed time (of the operation) and is displayed by CRT output automatically or upon an input "request" by the operating surgeon. The stable buffers used in these computations are automatically cleared at completion. The above computational operations occur in parallel to the following:

Replace the paragraph beginning on page 27, line 16 and ending on page 27, line 25 with the following paragraph:

After a 2 second preselected period of dwell, the controller and interface defeat front panel control of stimulus parameters and alter the stimulus delivery pattern to a series of single pulses of varying intensity. The controller and interface direct the provoked EMG responses to be captured individually into stable buffers. If the dwell is interrupted prior to completion of the stimulus sequence, the TCI-Time line is discontinued, the sequence of stimulator pulses is discontinued, the stable buffers are cleared of captured signal, the artifact-detection functions are enabled and stimulus parameters are reverted to front panel controls. However, interruption of the dwell after 2 seconds does not ~~Interfere~~ <u>interfere</u> with the completion of the parallel operations described above regarding the mathematical treatment of EMG ~~activity- provoked~~ <u>activity provoked</u> by single and paired stimulus pulses.

Replace the paragraph beginning on page 28, line 15 and ending on page 29,

line 5 with the following paragraph:

As described, the "TCI-Time line" ~~Is~~ is a multidimensional control algorithm or device utilizing information spanning both time and space. The continuous tissue contact dwell serves to initiate various series of operations through the TCI-Time line controller and interface. These operations may include simple or complex stimulus delivery paradigms, and corresponding data acquisition, analysis, display and archival storage procedures. The stimulation sequences and data handling algorithms proceed along different time lines, as per pre-programmed, parallel (processing) software algorithms. As long as the dwell continues, these operations proceed to completion in sequence. Alternatively, interruption of the dwell aborts all subsequent initiation of events along the dwell, but may allow some of the previously initiated events to reach completion as described above. The TCI-Time line controller directs operational events in different locations within the nerve integrity monitoring device. Production of stimulus pulses occurs in the stimulator portion of the monitor, while data acquisition, analysis, display and storage may occur in different locations, such as on the memory of a PCI card, CPU RAM memory or a hard drive. Thus the present TCI-Time line control system must account for multiple time dimensions and multiple locations within the monitoring device.

Replace the paragraph beginning on page 29, line 6 and ending on page 29, line 18 with the following paragraph:

Detection of tissue contact is preferably achieved by continuous stimulator circuit impedance measurement or continuous measurement of current flow with use of a separate sub-threshold current delivered downstream from actual pulsed stimuli to the

patient. Either of these methods will allow the detection of the temporal pattern caused by tapping the stimulator probe two or three times onto patient tissue (away from ~~Important~~ important structures) as a means of providing additional input to the controller through the tissue contact detection circuit. A "double" or "triple" tap of the stimulus probe may be preselected for altering the normal operation of the controller, such as initiating a display of previously stored data as a "time trend." That is, a "double tap" command may provoke the controller to display a time trend of a measured parameter, such as response threshold. The scalar value of stimulus intensity (mA), where the response threshold is achieved, is plotted against time (duration of the operation) to give the surgeon a clearer impression of how the nerve of interest has responded throughout the surgical procedure.

Replace the paragraph beginning on page 29, line 19 and ending on page 30, line 3 with the following paragraph:

Optionally, the control capabilities of the TCI-Time line are used for analyzing and storing data derived from detection of supra threshold events. Supra threshold events may be transferred from stable buffers, described previously with regard to "additional DSP" analysis of supra threshold events, and converted to file format for archival storage. The file of the digitized signal, its scalar DSP values (e.g., peak and average rRMS), and its channel number (or identity) may be archived (as in a spreadsheet) against the absolute or lapsed (operative) time of its appearance for later (off-line) retrieval. Such capabilities improve the ability to "tune" DSP parameters for greater accuracy in detecting appropriate events for analysis, for alerting the operating surgeon and for distinguishing artifacts from true EMG.

Replace the paragraph beginning on page 33, line 3 and ending on page 33, line 17 with the following paragraph:

Thus, the system delegates DSP functions to various components for rapid performance of mathematical operations and display of data. Complex stimulation paradigms are initiated by a digitally controlled stimulator, based upon temporal aspects of tissue contact by the main stimulus probe. The digital stimulator (or the controller executing the TCI-Time line algorithm) sends simultaneous signals through the PCI-interface to direct data to the appropriate buffers (or bins) for on-line analysis. Additional signals, either from the basic monitoring unit or internally generated on the PCI by pre-programmed algorithms, initiate pre-set data-display and data storage algorithms. Six to twelve different stimuli and a corresponding number of storage buffers may be employed for threshold detection. Alternating paired and single pulses will require at least three bins~~. One~~; one each for binning responses evoked by paired and single pulses, and a third for holding computed digital subtraction data. Optionally, within the two bins for single and paired responses or by combining the results of separate bins, repetitious responses may be used to compute a signal "average" for single and paired responses. The respective averages may be used to compute the digital subtraction data for the "third" bin.

Replace the paragraph beginning on page 33, line 22 and ending on page 34, line 2 with the following paragraph:

A preferred embodiment is that all changes made by off-line input procedures are transferred to the main unit of the nerve integrity monitor and "burned in" to non-volatile (EEPROM or flash) memory. As a result, the information transferred will be

protected from spurious voltage spikes and accidental unplugging. This ~~Is~~ is distinct from prior art methodology, where off-line changes are stored in volatile memory, which may be susceptible to spurious voltage spikes and accidental unplugging of equipment.

Replace the paragraph beginning on page 34, line 3 and ending on page 34, line 14 with the following paragraph:

Additional on-line flexibility is afforded through use of simple input devices which are convenient and easy to use, but not as comprehensive as the keyboard and mouse combination; in one embodiment, the stimulus probe is used as a pointing device for inputs to the controller. During surgery, or when "on-line", an electrical stimulus probe is preferably employed as a convenient controller input device and the TCI-Time line algorithm controls most on-line system operations, including which data are displayed to the operating surgeon on the CRT screen display~~, however~~, . However, the surgeon may periodically want to see additional information, such as a display of a measured parameter graphed as a function of time, over course of the procedure. The stimulus probe provides a convenient and simple input device for initiating such requests, since the surgeon is likely already holding the probe, and so need not put the probe down to use a keyboard, or the like.

Replace the paragraph beginning on page 34, line 18 and ending on page 35, line 4 with the following paragraph:

In addition to providing an indication of presence or absence of tissue contact, the tissue contact detection apparatus is configured to recognize specific signatures, such as a "double tap" or "triple tap" of ~~the-stimulus~~ the stimulus probe against non-sensitive patient tissue within the surgical field. The detection of these

predetermined signatures can be used to provide additional online input to the TCI-Time line controller. When such a pattern is detected, a separate signal is sent to the TCI-Time line controller for initiation of context sensitive, predetermined commands, a sequence analogous to a "double click" of a standard mouse when pointing to an icon in a Windows® compatible program. The identity of these commands are changeable, depending upon the monitoring context of the request; context is provided by the TCI-Time line algorithm. If the "double-click" occurs before the completion of a TCI-Time line controlled operation, the request is interpreted differently than for a double-click occurring after completion.

Replace the paragraph beginning on page 35, line 5 and ending on page 35, line 16 with the following paragraph:

The tapping pattern can differ among different users~~, in~~ . In order for the tapping pattern of a given user ~~is~~ to be recognized, a setup algorithm includes an adjustment method allowing the user to input his or her individual tapping pattern. Recognition of tapping patterns may be performed by "default" recognition settings within the tissue contact detection circuitry. However, because the temporal aspects of tapping may vary significantly among individual surgeons, the preferred system allows an individual surgeon's tapping signature to be captured for later recognition. It is preferred that this is performed early in the surgical procedure, before critical stages. For this procedure, a front panel or foot pedal switch is depressed, immediately after which the surgeon performs a "double tap" or "triple tap" signature. The pattern of impedance change or current flow change detected by the tissue contact detection circuitry is stored and used as a template for recognition of similar "signature" patterns at a later time.

Replace the paragraph beginning on page 35, line 17 and ending on page 35, line 21 with the following paragraph:

Also, when the double- or triple-tap input command is used, a sound sample or audible annunciation is preferably activated to indicate that the intended command has been successfully communicated. The sound sample ~~might~~ can be any form of effective audible feedback to the user (e.g., a sound of a standard mouse double-click or triple-click).

Replace the paragraph beginning on page 36, line 9 and ending on page 36, line 18 with the following paragraph:

A simple input device used in conjunction with the TCI-Time line algorithm alternatively includes two or three button operated switches accessed from a cylindrical handle. The two button configuration may be used in a manner similar to setting of a watch; one button selects options from a menu displayed on the nerve integrity monitor and the other button is used to choose a user preference or selection from the menu of options. Alternatively, a three-button input device provides more flexibility with forward and backward movement through a menu or series of menus, since the buttons could be used to scroll up, scroll down or select an option, respectively. The simple input device is readily kept sterile ~~on~~ in the operative field and its simplicity allows rapid data or control input and ease of use. Such a device does not require the use of the stimulating probe.

Replace the paragraph beginning on page 38, line 21 and ending on page 39, line 19 with the following paragraph:

Another aspect of the present invention is a method for reducing irritating ~~an~~ and

distracting noise from repetitive EMG activity made possible by the enhanced threshold detection strategy described above. Data from all (and exclusively) "intelligent" EMG channels is digitized and monitored by the enhanced threshold detection circuit, employing two probe windows as described, with an inter-probe interval of approximately one second. By DSP, the average rRMS is continuously computed for both windows and the ~~scala~~ scalar value is referenced against electrical silence. With the two probe window strategy, if only one window is active at a time, the duration of a supra threshold event must be less than the inter-probe interval. If both windows are active simultaneously, the duration is equal to or greater than the inter-probe interval. Since the vast majority of non-repetitive activity is less than one second in duration, an inter-probe interval of one second is able to effectively distinguish repetitive and non-repetitive responses. Repetitive responses are detected when both probe windows are simultaneously active. In the "automatic" squelch embodiment, the scalar values of average rRMS derived from the two probe windows are continuously scanned by a software comparator constructed in non-volatile memory. The comparator is configured to compare ongoing average rRMS values against a user preselected threshold value. If the threshold value is exceeded in both probe windows, a signal is generated which activates a muting switch to eliminate that particular channel from the audio (loudspeaker) signal to the operating surgeon. If other channels reach supra threshold levels of continuous repetitive EMG activity, more channels may be muted, except the last (quietest) channel. That is, no matter how much repetitive activity, at least one "intelligent" channel is preserved for continuous audio display of EMG signals to the operating surgeon. When the average rRMS values of both windows decrease below

threshold levels, the muting switch is automatically disabled.

Replace the paragraph beginning on page 42, line 21 and ending on page 43, line 22 with the following paragraph:

Referring specifically to Fig. 1 of the accompanying drawings, an intraoperative neurophysiological monitoring system 20 includes digitally controlled stimulator impedance and current flow detection circuit elements for use during intraoperative neurophysiological monitoring and preferably in conjunction with a tissue contact initiated event sequencing time line algorithm (TCI-Time line) for control of data acquisition, analysis, display and storage. A current source 20 is connected with parallel inputs to three electronic switches ("current-gates") CG-1,CG-2, and CG-3, 24, 26 and 28; although separate current sources for each stimulus output may be employed, a single current source is shown here. Each stimulus output includes a stimulus-controller (e.g., SC-1) 30 controlling the intensity, duration and temporal patterns of delivered stimulus-pulses. The controller is, in turn, connected with controlled by and responsive to a digital-interface (e.g., DI-1) 32 which is in turn connected to a CPU (not shown) and a comparator (e.g., C-C1) 34. Each stimulus output also includes a current detection circuit (e.g., CD-1) 36 and a stimulus isolation unit (e.g., SIU-1) 38. Each stimulus output includes an electronic switch (e.g., 24) which is responsive to and driven by tissue-contact detection. The present design uses impedance-detection as the means to detect ~~tissue-contact~~ tissue contact. Switches 24, 26 and 28 are kept in the open circuit position until ~~tissue-contact~~ tissue contact is detected at one of the cathode terminals at the output. Tissue contact produces a signal from the corresponding impedance-detection circuit to close the electronic

switch, the probe for which is in contact with tissue, and open circuits the other switches. Preferably, switches 24, 26 and 28 are configured so that only one switch (e.g., 24) can be closed at a time. Current flow is measured for each stimulus output by a current-flow detection circuit (e.g., 36), and the output of circuit 36 drives the digital indication or read out of current-flow for the corresponding stimulus output. The output signal of the current detection circuit 36 is responsive to measured current flow and is compared against the "user-intended" current level by comparator circuit 34.

Replace the paragraph beginning on page 43, line 23 and ending on page 44, line 18 with the following paragraph:

If the current value falls within predetermined limits (90-95%), comparator circuit 34 outputs an "enable" signal, to be used to trigger an "adequate-current" speech sample or tone, thereby providing audible feedback for the surgeon~~, the~~. The detection of the enable signal is a triggering event for execution of the TCI-Time line algorithm in the CPU and ~~Digital~~ digital interface 32. Each stimulus output includes a digital interface (e.g., 32) storing various stimulus paradigms, which are initiated in a pre-programmed fashion (as by the TCI-Time line algorithm) upon tissue-contact detection. Digital-interface 32 also directs data capture, analysis, display and storage in a pre-programmed fashion per the TCI-Time line. The interface 32 consists of two components, one of which is located in a system main monitoring unit, the other of which is located in a PCI-bus slot in a system computer. Digital interface 32 employs stimulus controller 30 which shapes the current provided from the current-source 22 into stimuli of pre-programmed intensity, duration, and having a pre-selected temporal pattern. The stimulus controller 30 is driven by digital interface 32, which stores

stimulus-paradigms in non-volatile memory and initiates the stimulus paradigms as pre-programmed within the TCI-Time line algorithm. Digital ~~Interface~~ interface 32 also controls functions relating to data acquisition, analysis, display, and storage through its connection with the CPU. For stimulus output #2, #3 or both, digital interface 32 may be configured to input measured values of stimulus circuit impedance and make pre-programmed adjustments of stimulus intensity, based upon impedance values. It is anticipated that stimulus output #1 will be used with a flush-tip stimulus probe for which such an application is not necessary.

Replace the paragraph beginning on page 48, line 6 and ending on page 48, line 17 with the following paragraph:

In addition to detecting and responding to a temporal pattern of continuous tissue contact of the stimulus probe, the stimulator of ~~Figs~~ Figs. 1 and 4 ~~are~~ is adapted for digital control. Stimulus intensity, pulse duration, and temporal pattern of stimuli presentation are controlled through a digital controller having a digital interface circuit 32. The interface 32 (and the accompanying CPU) stores pre-programmed stimulus algorithms or paradigms, preferably in non-volatile memory. The stimulus paradigms are preferably constructed off-line using appropriate stimulus control algorithm development software and is preferably loaded or burned into a non-volatile Read Only Memory (ROM) chip, included within the interface. During a monitoring procedure, contact with tissue will trigger a predefined sequence of events called, for purposes of nomenclature, a Tissue Contact Initiated (TCI)-Time line, thereby activating the stored stimulus paradigms in a pre-programmed manner.

Replace the paragraph beginning on page 48, line 18 and ending on page 49,

line 2 with the following paragraph:

Front panel controls for monitoring system 20 consist of basic stimulus intensity controls. Stimulus, pulse duration and pulse repetition rate are preferably adjusted in a limited manner by recessed DIP-switches or other user-accessed, but less prominent controls. The remaining stimulator controls are actuated through the digital CPU interface 32, such as via a PCI bus. As discussed above, monitoring parameters and complex stimulus paradigms are stored via ~~non volatile~~ non-volatile, programmable memory (e.g., flash memory, EEPROM). The digitally controlled stimulator executing the TCI event-sequencing time line also communicates with a CPU (not shown) based data storage and analysis apparatus to direct binning or storing of responses and to trigger archival data storage, analysis and display paradigms.

Replace the paragraph beginning on page 49, line 16 and ending on page 49, line 21 with the following paragraph:

Returning now to Fig. 4, the intraoperative neurophysiological monitoring system 100 includes digitally controlled stimulator current flow detection circuit CD-1, 106 and a second, downstream current source CS-2, 104, and is well suited to performing the method of the present invention with current flow detection only. Current source 108 comprises the main source of current to provide nerve stimulation; although separate current sources for each stimulus output may be employed, a single source is shown.

Replace the paragraph beginning on page 49, line 22 and ending on page 50, line 12 with the following paragraph:

Current Source #2, 104 provides continuous, sub-threshold current through the cathode of stimulus output probe 102 for detection of ~~tissue-contact~~ tissue contact. As

above, the switches or current gates CG-1, CG-2 and CG-3 are actuated or driven by tissue contact detection. The present design uses current-flow detection as the means to detect ~~tissue-contact~~ tissue contact. The switches ("current-gates") are kept in the open-position until ~~tissue-contact~~ tissue contact is detected at one of the cathode terminals at the output which produces a signal from the corresponding impedance-detection circuit to close the electronic switch for the probe (e.g., 102) in contact with tissue, and opens the others~~, as~~ . As above, the switches are configured so that only one switch can be closed at a time. Each stimulus output also has a stimulus-controller SC-1 that effects the intensity, duration and temporal patterns of delivered ~~stimulus-pulses~~ stimulus pulses. The controller is, in turn, controlled by a digital-interface DI-1. Current-flow will be measured for each stimulus output by a current-flow detection circuit (e.g. CD-1). Second current-source 104 injects a continuous, sub-threshold current beyond the current-gate CG-1, which is used for the detection of ~~tissue-contact~~ tissue contact. During delivery of ~~"stimulus-current"~~ "stimulus current" the output of the CS-2 circuit is used to drive the digital readout of current-flow for the corresponding stimulus output (e.g., probe 102).

Replace the paragraph beginning on page 50, line 18 and ending on page 51, line 2 with the following paragraph:

Digital interface DI-1, 114 stores various stimulus-paradigms which are initiated in a pre-programmed fashion (TCI-Time line) by detection of ~~tissue-contact~~ tissue contact of the primary stimulus probe 102. Digital interface 114 also directs data capture, analysis, display and storage in a pre-programmed fashion per the TCI-Time line. Interface 114 consists of two components, one of which is located in the main unit,

the other of which is located in a PCI-bus slot in the computer. The digital interface 114 controls a stimulus controller SC-1, 116 which shapes the current provided from current source 108 into stimuli of pre-programmed intensity, duration, and temporal pattern. The digital interface DI-1, 114 also controls functions relating to data acquisition, analysis, display, and storage through a connection with a CPU (not shown).

Replace the paragraph beginning on page 51, line 23 and ending on page 53, line 2 with the following paragraph:

Fig. 6 is a top view of an artifact detection electrode 130 for use during intraoperative neurophysiological monitoring to provide a reliable means of detecting electromagnetic and current artifacts, occurring in the physical-proximity of multiple active recording electrodes. Signal output from artifact-detection electrode 130 is used in a simple logic paradigm for the purposes of distinguishing electromagnetic (EM) and current artifacts from biophysiological responses, and is useful to detect when general anesthesia is becoming inadequate or light. Probe 130 is well suited for detection and identification of artifacts as an aid to interpretation, and can be placed in different groups of muscles to obtain different measurements. For the purposes of this description, "'intelligent" refers to electrode sites ~~Involving~~ <u>involving</u> important "monitored" muscles, supplied or enervated by a particular nerve of ~~Interest~~ <u>interest</u>. Non-intelligent refers to other electrode sites within or outside of muscles, not supplied by the nerve of ~~Interest~~ <u>interest</u>. Current artifacts and electromagnetic field noise may best be detected by electrode 130 when inserted proximate to the recording field, but not in the (intelligent) muscles supplied by the nerve being monitored. Electrical events, simultaneously recorded in both "intelligent" electrodes (placed in muscles supplied by

the nerve being monitored) and a "non-intelligent" artifact detection electrode, may be unambiguously interpreted as electrical artifacts. If the artifact detection electrode is placed in a nearby (non-intelligent) muscle not supplied by the nerve being monitored, it may also serve to detect light anesthesia. If repetitive EMG activity is simultaneously observed in monitored muscles and other muscles, it may be interpreted that the patient is beginning to wake up from anesthesia. The anesthesiologist may use this information to maintain adequate levels of anesthesia throughout the procedure. The operating surgeon may also be reassured that the observed nerve irritability is not related to surgical manipulations. This artifact detection strategy is abetted by the construction of artifact-detection electrode 130 which is a modification of the electrode design of U.S. Patent 5,161,533 (as discussed above). The modification provides a greater impedance imbalance between the two electrode leads 132, 134, thereby reliably enhancing the antenna-like qualities of the probe and the susceptibility for detecting current and electromagnetic artifacts occurring in the immediate proximity of multiple electrodes placed in muscles supplied by the nerve of interest.

Replace the paragraph beginning on page 58, line 5 and ending on page 58, line 16 with the following paragraph:

Turning now to ~~Figs~~ Figs. 7, 8 and 9, another aspect of the present invention relates to a versatile, precise and ergonomic method of control for multiple data-management procedures associated with intraoperative neurophysiological monitoring. The method (discussed above in conjunction with the TCI time line algorithm) involves digital control of a preprogrammed array of electrical stimuli and a coordinated series of data acquisition, analysis, display and storage algorithms initiated

through the detection of the temporal pattern of electrical stimulus probe use and is particularly advantageous in the field of intraoperative electromyographic (EMG) monitoring in association with periods of electrical stimulus probe use. Certain aspects of the control system may be linked to supra-threshold detection of EMG or artifact activity. Moreover, the method and algorithm may be adapted to other fields in which a probe is used for data acquisition and where data-management operations can be linked to monitored aspects of its use.

Replace the paragraph beginning on page 59, line 3 and ending on page 59, line 13 with the following paragraph:

Referring now to the upper portion of Fig. 7, showing a graphical representation of a pre-programmed set of electrical stimulus pulses of varying intensities used in the intraoperative monitoring of responses to stimulus pulses, the vertical axis is graduated in milliamps (mA) of stimulus current applied through a stimulus probe and the horizontal axis overhead is a time scale in seconds. A preprogrammed pattern or paradigm of stimulus pulses, as illustrated, preferably includes a first pair 150 of stimulus pulses spaced at less than 100 mS apart and having equal amplitudes of approximately 0.10 mA~~, these~~. These are called paired pulses 150 and are followed at a spacing of approximately 100 mS by a single pulse 152 having an equal amplitude, 0.10 mA. Preferably, the pattern next includes another set of paired pulses 150, followed in alternate succession by another single pulse 152.

Replace the paragraph beginning on page 59, line 17 and ending on page 60, line 8 with the following paragraph:

Returning to Fig. 8, intraoperative neurophysiological monitoring system 200

includes current source 208 which generates stimulus current and is connected to the stimulus controller 210 which controls the intensity, duration and temporal patterns of delivered stimulus pulses. Controller 210 is, in turn, responsive to and controlled by a digital-interface (DI-1) 204. Current-flow is measured for each stimulus output by a current-flow detection circuit 212, the output of this circuit will be used to drive the digital-readout of current-flow for the corresponding stimulus output. The output of the current flow detection circuit 212, relating to measured current-flow, is compared against the user selected level by a comparator circuit 214, and if the value falls within predetermined limits (90-95%), the comparator circuit 214 optionally puts out an "enable" signal, to be used to trigger an "adequate-current" speech sample or tone; it may also be incorporated as an "enable" signal for the TCI-Time line. Digital-interface 204 stores various stimulus-paradigms, which are initiated in a pre-programmed fashion (TCI-Time line) by detection of ~~tissue-contact detection~~ tissue contact. The digital interface also directs data capture, analysis, display and storage in a preprogrammed fashion per the TCI-Time line. The interface consists of two components, one of which is located in the main unit, the other of which is located in a PCI-bus slot in the computer. ~~For optional~~

Replace the paragraph beginning on page 60, line 9 and ending on page 61, line 4 with the following paragraph:

For output #2, #3 or both, the digital-interface may be configured to input measured-values of stimulus-circuit impedance and make pre-programmed adjustments of stimulus intensity, based upon impedance values. It is anticipated that stimulus output #1 will be used with a flush-tip stimulus probe for which such an

application is not necessary. Impedance detection circuit ID-1 220 provides an indication of ~~tissue-contact~~ tissue contact and ~~to measure nominal~~ a measurement of stimulus-circuit impedance. Detection of ~~tissue-contact~~ tissue contact can be used to initiate the TCI-Time line and measurement of impedance can be used to provide a "quality-check" of the stimulus-circuit integrity and provide a means of adjusting stimulus intensity to the level of current-shunting. For impedance measurement, the impedance-detection circuit provides a small, sub-threshold signal that is detected to establish continuity. Patient connections for impedance detection circuit 220 ~~is~~ are electrically or optically isolated by isolation circuit 222. A comparator ~~INDEPENDENT CLAIM 1~~ 224 receives output from impedance detection circuit 220 and computes scalar representations or values of stimulus circuit impedance and provides an output digital interface 204 to drive the various data-handling operations and preprogrammed stimulus intensity adjustments. Digital interface 204 connects the stimulator with a CPU 206, so that data acquisition, analysis, display and storage can be coordinated. Digital interface 204 and CPU 206 execute spreadsheeting of data and drive a graphic display 208 (e.g., a CRT or LCD). Digital interface 204 is preferably configured to direct the capture of digitally-sampled audio and video data corresponding to signal data. CPU 206 is preferably programmed to store files for later retrieval and "off-line" analysis.

Replace the paragraph beginning on page 61, line 5 and ending on page 61, line 18 with the following paragraph:

As shown in Fig. 9 , intraoperative neurophysiological monitoring system 300 includes current source 308 which generates stimulus current and is connected to the stimulus controller 310 which controls the intensity, duration and temporal patterns of

delivered stimulus pulses. Controller 310 is, in turn, responsive to and controlled by a digital-interface (DI-1) 304. Current-Source #2 , CS-2, 309 injects a small, continuous, sub-threshold current as a probe signal to provide means of tissue-contact detection. ~~Current-flow~~ Current flow is measured for each stimulus output by a current-flow detection circuit 312~~,~~ . ~~the~~ The output of this circuit will be used to drive the digital-readout of ~~current-flow~~ current flow for the corresponding stimulus output. The output of the ~~current-flow~~ current flow detection circuit 312, relating to measured ~~current-flow~~ current flow, is compared against the user selected level by a comparator circuit 314, and if the value falls within predetermined limits (90-95%), the comparator circuit 314 optionally puts out an "enable" signal, to be used to trigger an "adequate-current" speech sample or tone; it may also be incorporated as an "enable" signal for the TCI-Time line.

Replace the paragraph beginning on page 62, line 5 and ending on page 62, line 7 with the following paragraph:

Quantitative data on nerve function is mainly acquired through the use of an electrical stimulus probe (e.g., 202 or 302, as shown in ~~Figs~~ Figs. 8 and 9), provoking electromyographic responses for quantitative analysis.

Replace the paragraph beginning on page 62, line 8 and ending on page 63, line 19 with the following paragraph:

The inventor has observed that surgeons use the stimulus probe (e.g., 202) differently for locating and ~~"Mapping"~~ "mapping" than for quantitative analysis of the functional status of nerves of interest. Temporal aspects of stimulus probe use can be monitored by the tissue contact detection capability within the digital stimulator as

described previously. A signal is generated in the stimulator that relates to the period of continuous contact of the stimulator probe with patient tissue. The signal continues as long as continuous tissue contact is maintained and is delivered to a system controller, which is able to initiate multiple predetermined sequential and parallel operations within the nerve integrity monitor, as shown in the central flow chart portion of Fig. 7. These operations relate to delivery of preprogrammed stimulus sequences and to the acquisition, analysis, display and archival storage of EMG data. Whether the predetermined operations are initiated or completed depends upon the duration of continuous tissue contact. For example, as shown in the flowchart portion at the bottom of Fig. 7, if the duration of continuous tissue contact is less than a preselected period of approximately one or two seconds, the controller will maintain the operational status of the nerve ~~Integrity~~ integrity monitor in the "search" mode. However, if the duration of continuous tissue contact exceeds the preselected time period, the stimulator or controller may alert the surgeon with an indicator tone and the controller will automatically change the operational status of the nerve integrity monitor to a quantitative assessment mode and provide a preprogrammed sequence of quantitative assessment stimulus pulses 160, as shown in the upper portion of Fig. 7. A monitoring indicator tone may also be designed or configured to signify whether adequate current and/or stimulator circuit impedance has been achieved, as an indication of quality assurance, as discussed above. From the time of tissue contact detection, a digital clock is initiated, controlling a preprogrammed sequence of events through a controller interface DI-1 (as shown in Figs 8 and 9). For the purposes of this description, the period of continuous tissue contact of the stimulus probe is termed the "dwell" or "dwell

time", and the series of preselected operational changes provoked by the "dwell" is termed, the "Tissue Contact Initiated Event Sequencing Time line" or "TCI-Time line" and is illustrated, in part, in the middle and ~~loser~~ lower flow charts included in Fig. 7. The control method to be described is designed for use with the main stimulus probe (e.g., probes 202, 302 connected to stimulus output #1 in a multi-stimulus output system, as described above) and may be used to control all functions of the nerve integrity monitor in a preselected fashion, by execution of an algorithm stored in memory. The described methodology need not be limited to medical applications, in that the use of any probe, where its period of dwell can be measured, may be similarly configured to control multiple functions. The following description involves the preferred embodiment, although many possible sequence strategies are available through the TCI-Time line:

Replace the paragraph beginning on page 63, line 20 and ending on page 64, line 17 with the following paragraph:

Through the associated controller and controller interface (e.g. the Digital interface DI-1 204, of Fig. 8 and 304, of Fig. 9), the onset of dwell causes the artifact-detection circuit to be suspended ("defeated") throughout its duration and a preset pattern of stimulus pulses, the intensity of which is determined by front panel controls, will be delivered through the stimulator probe for locating and ~~"mapping'~~ "mapping" the physical contour of the nerve of ~~Interest~~ interest. After a preselected dwell time of approximately one second (as shown in the upper part of Fig. 7), front panel control of stimulus parameters is defeated, the pattern of stimuli is changed from single pulses 152 to alternating paired pulses 150 with single pulses 152, the intensity

of which is somewhat greater (supra maximal), and the provoked EMG responses are digitized and individually captured into stable buffers. If the dwell is interrupted before a dwell of 2 seconds, the TCI-Time line is inactivated or aborted, the artifact-detection circuit ~~Is~~ is enabled, the stable buffers are cleared of captured signal and pulsed stimuli are no longer delivered through the stimulus probe. After a 2 second preselected period of dwell, the controller and associated interface initiate a signal processing sequence, where the captured responses in stable buffers are analyzed by averaging the single and paired responses separately and computing the difference between the paired and single response by digital subtraction. The magnitude of the single and digitally subtracted responses are computed and compared. A scalar value relating to a ratio of the magnitudes of the digitally subtracted response and the single response is stored in a spreadsheet against the absolute or lapsed time (of the operation) and is displayed by CRT output automatically or upon an input "request" by the operating surgeon. The stable buffers used in these computations are automatically cleared at completion. The above computational operations occur in parallel to the following:

Replace the paragraph beginning on page 64, line 18 and ending on page 65, line 2 with the following paragraph:

After a 2 second preselected period of dwell, the controller and interface defeat front panel control of stimulus parameters and alter the stimulus delivery pattern to a series of single pulses of varying intensity 160. The controller and interface direct the provoked EMG responses to be captured individually into stable buffers. If the dwell is interrupted prior to completion of the stimulus sequence, the TCI-Time line is discontinued, the sequence of stimulator pulses is discontinued, the stable buffers are

cleared of captured signal, the artifact-detection functions are enabled and stimulus parameters are reverted to front panel controls. However, interruption of the dwell after 2 seconds does not ~~Interfere~~ interfere with the completion of the parallel operations described above regarding the mathematical treatment of EMG ~~activity~~ activity provoked by single and paired stimulus pulses.

Replace the paragraph beginning on page 65, line 17 and ending on page 66, line 7 with the following paragraph:

As described, the "TCI-Time line" ~~Is~~ is a multidimensional control algorithm or device utilizing information spanning both time and space. The continuous tissue contact dwell serves to initiate various series of operations through the TCI-Time line controller and interface. These operations may include simple or complex stimulus delivery paradigms, and corresponding data acquisition, analysis, display and archival storage procedures. The stimulation sequences and data handling algorithms proceed along different time lines, as per pre-programmed, parallel (processing) software algorithms. As long as the dwell continues, these operations proceed to completion in sequence. Alternatively, interruption of the dwell aborts all subsequent initiation of events along the dwell, but may allow some of the previously initiated events to reach completion as described above. The TCI-Time line controller directs operational events in different locations within the nerve integrity monitoring device. Production of stimulus pulses occurs in the stimulator portion of the monitor, while data acquisition, analysis, display and storage may occur in different locations, such as on the memory of a PCI card, CPU RAM memory or a hard drive. Thus the present TCI-Time line control system must account for multiple time dimensions and multiple locations within the monitoring

device.

Replace the paragraph beginning on page 66, line 8 and ending on page 66, line 20 with the following paragraph:

Detection of tissue contact is preferably achieved by continuous stimulator circuit impedance measurement or continuous measurement of current flow with use of a separate sub-threshold current delivered downstream from actual pulsed stimuli to the patient. Either of these methods will allow the detection of the temporal pattern caused by tapping the stimulator probe two or three times onto patient tissue (away from ~~Important~~ important structures) as a means of providing additional input to the controller through the tissue contact detection circuit. A "double" or "triple" tap of the stimulus probe may be preselected for altering the normal operation of the controller, such as initiating a display of previously stored data as a "time trend." That is, a "double tap" command may provoke the controller to display a time trend of a measured parameter, such as response threshold. The scalar value of stimulus intensity (mA), where the response threshold is achieved, is plotted against time (duration of the operation) to give the surgeon a clearer impression of how the nerve of interest has responded throughout the surgical procedure.

Replace the paragraph beginning on page 66, line 21 and ending on page 67, line 5 with the following paragraph:

Optionally, the control capabilities of the TCI-Time line are used for analyzing and storing data derived from detection of supra threshold events. Supra threshold events may be transferred from stable buffers, described previously with regard to "additional DSP" analysis of supra threshold events, and converted to file format for

archival storage. The file of the digitized signal, its scalar DSP values (e.g., peak and average rRMS), and its channel number (or identity) may be archived (as in a spreadsheet) against the absolute or lapsed (operative) time of its appearance for later (off-line) retrieval. Such capabilities improve the ability to "tune" DSP parameters for greater accuracy in detecting appropriate events for analysis, for alerting the operating surgeon and for distinguishing artifacts from true EMG.

Replace the paragraph beginning on page 67, line 6 and ending on page 68, line 2 with the following paragraph:

Preferably, audio and video capture devices are integrated into the system to perform audio and video data capture functions. An independent method of distinguishing artifact and EMG supra threshold events is to interpret events in the context of the surgical procedure. If the supra threshold event occurred exactly at the time of a surgical manipulation, it may be interpreted as a mechanically stimulated (hence non-repetitive) EMG event. Alternatively, if the event appears to occur independently of surgical manipulations, it is interpreted as either artifact or non-localizing (repetitive) EMG. Relatively brief (3-5 seconds) periods of digitized audio signal of the sound delivered to the surgeon through the loudspeaker in the nerve integrity monitor and digitized video of the surgical procedure, from a (microscope or hand held) camera monitoring the surgical field, is adequate to interpret the "context" of a supra threshold event. Audio and video signal may be digitized and held in FIFO "scroll" buffers within the nerve integrity monitor. For investigational purposes, the logical circuits used for detection of supra threshold events may send a signal to the TCI-Time line controller when certain preselected supra threshold events are detected;

the signal provokes the TCI-Time line controller to cause the capture of digitized audio and video for an interval starting 2-4 seconds before and ending one second after the onset of the supra threshold event. The captured audio and video can then be converted to file form (*.avi, *.mpg or equivalent) and archived along with the signal data mentioned above. Such capability tremendously facilitates evaluation (validation) of various methods of event (artifact and EMG response type) detection for accuracy and effectiveness.

Replace the paragraph beginning on page 68, line 3 and ending on page 68, line 14 with the following paragraph:

With the present control system, temporal aspects of stimulus probe use can be made to control an entire quantitative analysis paradigm in a pre-programmed, preset manner, based upon the needs of the user. This will involve a mix of sequential and parallel operations and smooth operation is dependent upon a seamless digital CPU interface (e.g., 204 or 304) for control of data acquisition, analysis and display, preferably in a Windows® based software system. The algorithm steps or command sequences and interrupt interpretations are stored on ~~non volatile~~ non-volatile memory, such as EEPROM or "flash memory," providing fast online operation in a controller which is readily reprogrammed or modified off-line by CPU-interface. At present, the prevailing standard digital interface is the Peripheral Components Interface (PCI); it is to be understood that future developments may provide equivalents to the PCI standard. Accordingly, the following discussion is a description of but one exemplary embodiment which happens to include a PCI circuit card.

Replace the paragraph beginning on page 70, line 5 and ending on page 70, line

20 with the following paragraph:

Thus, the system delegates DSP functions to various components for rapid performance of mathematical operations and display of data. Complex stimulation paradigms in the form of software algorithms are initiated by a digitally controlled stimulator, based upon temporal aspects of tissue contact by the main stimulus probe. The digital stimulator (or the controller executing the TCI-Time line algorithm) sends simultaneous signals through the PCI-interface to direct data to the appropriate buffers (or bins) for on-line analysis. Additional signals, either from the basic monitoring unit or internally generated on the PCI by pre-programmed algorithms, initiate pre-set data-display and data storage algorithms. Six to twelve different stimuli and a corresponding number of storage buffers may be employed for threshold detection. Alternating paired and single pulses will require at least three bins~~. One~~ :one each for binning responses evoked by paired and single pulses, and a third for holding computed digital subtraction data. Optionally, within the two bins for single and paired responses or by combining the results of separate bins, repetitious responses may be used to compute a signal "average" for single and paired responses. The respective averages may be used to compute the digital subtraction data for the "third" bin.

Replace the paragraph beginning on page 71, line 1 and ending on page 71, line 6 with the following paragraph:

In the preferred embodiment, all changes made by off-line input procedures are transferred to the ~~Main~~ main unit of the nerve integrity monitor and "burned in" to non-volatile (EEPROM or flash) memory. As a result, the information transferred will be protected from spurious voltage spikes and accidental unplugging. This ~~Is~~ is distinct

from prior art methodology, where off-line changes are stored in volatile memory, which may be susceptible to spurious voltage spikes and accidental unplugging of equipment.

Replace the paragraph beginning on page 71, line 17 and ending on page 72, line 2 with the following paragraph:

Threshold-detection is based on measured signal power (such as root-mean-square) ~~is monitored~~ for each channel. As signal power increases, the threshold is automatically elevated in order to avoid threshold detection of background EMG activity. One embodiment of this method is to sample signal-power at intervals, and to hold the determinations in temporary memory, such as in a digital scroll method. In order for a supra-threshold, signal event to be detected, one or more consecutive signal power determinations would have to be greater, by a preset difference level, than the signal power sampled one second before them. An alternative is to require that one or more consecutive signal-power determinations be greater than the power levels one second before and one-second after, thereby limiting threshold-detection to just brief responses.

Replace the paragraph beginning on page 76, line 5 and ending on page 76, line 16 with the following paragraph:

The tapping pattern can differ among different users, in order for the tapping pattern of a given user ~~is~~ <u>to be</u> recognized, a setup algorithm includes an adjustment method allowing the user to input his or her individual tapping pattern. Recognition of tapping patterns may be performed by "default" recognition settings within the tissue contact detection circuitry. However, because the temporal aspects of tapping may vary significantly among individual surgeons, the preferred system allows an individual

surgeon's tapping signature to be captured for later recognition. It is preferred that this is performed early in the surgical procedure, before critical stages. For this procedure, a front panel or foot pedal switch is depressed, immediately after which the surgeon performs a "double tap" or "triple tap" signature. The pattern of impedance change or current flow change detected by the tissue contact detection circuitry is stored and used as a template for recognition of similar "signature" patterns at a later time.

Replace the paragraph beginning on page 76, line 17 and ending on page 76, line 21 with the following paragraph:

Also, when the double- or triple-tap input command is used, a sound sample or audible annunciation is preferably activated to indicate that the intended command has been successfully communicated. The sound sample ~~might~~ can be any form of effective audible feedback to the user (e.g., a sound of a standard mouse double-click or triple-click).

Replace the paragraph beginning on page 77, line 18 and ending on page 78, line 2 with the following paragraph:

A simple input device used in conjunction with the TCI-Time line algorithm alternatively includes two or three button operated switches accessed from a cylindrical handle. The two button configuration may be used in a manner similar to setting of a watch; one button selects options from a menu displayed on the nerve integrity monitor and the other button is used to choose a user preference or selection from the menu of options. Alternatively, a three-button input device provides more flexibility with forward and backward movement through a menu or series of menus, since the buttons could be used to scroll up, scroll down or select an option, respectively. The simple input

device is readily kept sterile ~~on~~ in the operative field and its simplicity allows rapid data or control input and ease of use. Such a device does not require the use of the stimulating probe.

Replace the paragraph beginning on page 78, line 7 and ending on page 78, line 23 with the following paragraph:

Turning now to another aspect of the present invention, a squelch control method is provided for use during multi-channel intraoperative neurophysiological monitoring for the purposes of enhancing the surgeon's ability to hear brief localizing (non-repetitive) electromyographic responses during periods of significant background activity. The squelch control method is based upon the method for detecting repetitive EMG activity made possible by the enhanced threshold detection strategy described above. Data from all (and exclusively) "intelligent" EMG channels is digitized and monitored by the enhanced threshold detection circuit, employing two probe windows as described, with an inter-probe interval of approximately one second. By DSP, the average rRMS is continuously computed for both windows and the ~~scala~~ scalar value is referenced against electrical silence. With the two probe window strategy, if only one window is active at a time, the duration of a supra threshold event must be less than the inter-probe interval. If both windows are active simultaneously, the duration is equal to or greater than the inter-probe interval. Since the vast majority of non-repetitive activity is less than one second in duration, an inter-probe interval of one second is able to effectively distinguish repetitive and non-repetitive responses. Repetitive responses are detected when both probe windows are simultaneously active.